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Original Article

Evaluation and comparison of diagnostic accuracy of early warning scores in the diagnosis of traumatic brain injury: A prospective study

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Abstract

Objective: When dealing with patients with possible traumatic brain injury, prehospital emergency personnel must make decisions quickly with very little data. Determining the amount of risk that threatens patients can lead to making correct treatment decisions. The present study aimed to determine and compare the diagnostic accuracy of early warning scores in prehospital care for the diagnosis of traumatic brain injury.

Methods: This prospective study was conducted from December 2023 to January 2025 at hospitals affiliated with Tehran University of Medical Sciences. Sampling was performed purposefully, and non-randomly and 250 trauma patients were enrolled in the study. Data collection was carried out utilizing a demographic questionnaire and various scoring systems, including the National Early Warning Score (NEWS2), Modified Early Warning Score (MEWS), Triage Early Warning Score (TEWS), and Modified Emergency Medical Score (MEMS). The data were analyzed using SPSS software.

Results: The mean age of the patients was 40.90 ± 15.78. Accident (56.8%) was the most common mechanism of trauma, and multiple trauma (56%) was the most common type of trauma. The National Early Warning Score 2 showed the highest diagnostic accuracy with sensitivity of 82.2%, specificity of 81.1%, and area under the curve of 0.889(. The results of the independent *t*-test showed that the mean score of the NEWS2 in prehospital care for patients with an initial diagnosis of traumatic brain injury after 72 hours (12.3 ± 29.4) was significantly lower compared to other patients (08.3 ± 73.7) ($P < 0.001$).

Conclusion: While all four early warning scores were good at detecting ICU admission, there were significant differences in their performance measures. The higher diagnostic accuracy of the National Early Warning Score 2 makes it a valuable tool in identifying patients with traumatic brain injury.

Keywords: Early warning score, Trauma nursing, Intensive care units

Introduction

In the healthcare system, prehospital emergency care is one of the most fundamental service-providing units, responsible for providing immediate and timely response to accidents, medical emergencies, and trauma (1). Prehospital emergency personnel are often recognized as the first providers of medical services (2). Their presence at the trauma scene places them in a unique position, enabling them to have a comprehensive understanding of the factors contributing to the injury (3). In prehospital settings, they make critical decisions regarding treatment initiation, the need for intensive care, and the patient's ultimate destination (3). However, studies do not consistently support the accuracy of all clinical judgments made by emergency medical technicians (2-4).

When encountering a patient with a traumatic brain injury in a prehospital environment, prehospital emergency personnel must perform a systematic assessment and make decisions rapidly with minimal data. Predicting the need for advanced support measures for a trauma patient at the scene or en route is crucial for preventing secondary injuries related to hypoxia or hypotension (5-7). Perhaps the most significant reason for technicians' inability to make sound decisions is the lack of a suitable tool and criterion for accurately diagnosing the severity of the patient's condition (8-10).

In this regard, and to implement evidence-based practices, numerous scoring systems have been proposed

for use in emergency centers to identify patients at risk of vital organ dysfunction (11,12). Early warning scores (EWS) are tools that can assist professionals in clinical decision-making, predicting the risk of deterioration, monitoring the patient's recovery, and facilitating communication between different levels of care, particularly to enhance patient safety (13, 14). Early warning scores consist of a sum of points that allows care providers to quickly assess a patient's condition with limited data in a short amount of time and, based on the score obtained from the tool within a defined range, make decisions about the type and manner of treatment. The use of these tools usually follows a similar pattern, and entering the relevant information into the tool is straightforward (15).

Scoring and prediction systems for traumatic brain injury (TBI) have been used in several studies in emergency settings outside Iran. However, even in these studies, which are not numerous, patients transported by prehospital emergency services were evaluated in the emergency department using physiological tools. Alternatively, some studies were retrospective and relied solely on information available in patient files (16, 17). Williams et al in a review study aimed at examining early warning systems used in prehospital emergency settings, showed that these systems are helpful for predicting important clinical outcomes. However, there is significant heterogeneity among different early warning systems, making it difficult to generalize these tools across various settings (18).

Furthermore, the working conditions of healthcare personnel vary based on their specialization. Therefore, studies that can help improve the quality of decisions made by healthcare personnel regarding the level of intensive care required for patients are necessary. This is because improving the quality of decisions made in the prehospital emergency setting can reduce medical errors resulting from incorrect decision-making (19). The present study aimed to determine and compare the diagnostic accuracy of early warning scores in prehospital care for the diagnosis of traumatic brain injury.

Methods

This was a prospective observational study conducted in the emergency departments of hospitals affiliated with Tehran University of Medical Sciences from December 2023 to January 2025. This study was approved by the Research Ethics Committee of the Tehran University of Medical Science, Iran (code IR.TUMS.FNM.REC.1402.129).

Sampling was performed purposefully and non-randomly from trauma patients requesting emergency or prehospital services through self-reporting or by others from the 115 Emergency Dispatch Center. To determine the minimum required sample size for estimating the diagnostic accuracy of early warning scores at a 95% confidence level and with an estimation precision of $d = 0.05$, and considering the reported area under the ROC curve of 0.8, the required sample size of 250 individuals was obtained after plugging the values into the following formula (20).

$$n = \frac{z^2_{1-\alpha/2}\, pq}{d^2} = \frac{1.96^2 \times 0.8 \times 0.2}{0.05^2} = 245.86 \approx 250$$

The inclusion criteria for the study included age over 18 years, transfer to the hospital via the 115 emergency service, and completion of an informed consent form. The exclusion criteria included transfer via non-115 emergency service, confirmed pregnancy, and individuals in the six-week postpartum period. Exclusion criteria also included discharge from the hospital emergency department at the patient's own request, transfer to another hospital, and pregnancy if identified during evaluations within 72 hours of admission.

After presenting the introduction letter to the hospital officials and explaining the study's objectives, the informed consent form was initially completed by the patient. If the patient was unable to complete the informed consent form (due to lack of consciousness, distress, or not having an awareness of oneself, time, and place), a legal guardian was asked to complete the form.

The data collection method employed a questionnaire for demographic information and early warning scores. The demographic questionnaire included variables such as age, gender, marital status, mechanism of trauma, type of trauma, and actions taken at the scene, such as tracheal intubation, use of analgesics, and the application of advanced immobilization techniques and splinting, as well as the time taken for transfer from the scene to the hospital. To assess TBI, validated scales that did not require further validation or reliability testing, could be easily applied in a prehospital setting, and utilized either single or multi-parameter systems based on standard vital signs or simple clinical observations were selected. Accordingly, four warning tools, which are explained below, were selected.

National Early Warning Score 2 (NEWS2): This scale is designed for use in adults over 16 years of age and is not applicable for assessing pregnant women. It assesses seven parameters: pulse rate, systolic blood pressure, temperature, oxygen saturation, and AVPU (awake, responsive to verbal stimulus, responsive to pain, unresponsive). A higher score indicates a need for increased monitoring and care.

Modified Early Warning Score (MEWS): This scale assesses the patient by evaluating pulse rate, systolic blood pressure, temperature, and AVPU. The scale yields a score ranging from zero to a maximum of 14. Higher scores indicate a more unstable hemodynamic status. A score higher than 5 is considered critical and requires intensive care (21).

Triage Early Warning Score (TEWS): This scale assesses the patient by evaluating pulse rate, blood pressure, temperature, systolic blood pressure, mobility level, and the presence or absence of trauma. A score equal to or higher than 7 indicates an emergency triage level, 6–5 requires very urgent care, 4–3 requires urgent care, and 2–0 requires routine care (22).

Modified Rapid Emergency Medicine Score (MREMS): This scale assesses pulse rate, respiratory rate, systolic blood pressure, oxygen saturation, Glasgow Coma Scale, and patient age. The scoring range is from zero to 26, with higher scores indicating a worsening patient condition (21).

The questionnaires were completed by researchers in the hospital's emergency department, using information gathered from emergency medical technicians. The vital signs necessary for inclusion in the early warning scores were measured on-site by the emergency medical technicians and recorded in the early warning score form in the emergency department. The status of patients regarding discharge from the emergency department, need for hospitalization, admission to the intensive care unit, and death within 48 hours after trauma was documented 72 hours after the incident and the visit to the emergency department.

For data analysis, descriptive statistics and metrics such as mean, standard deviation, and frequency of the demographic information of the study participants were examined. Using analytical statistics and hypothesis testing, after the normality test, statistical tests were conducted to calculate sensitivity and specificity to compare the accuracy of four diagnostic tests. SPSS software version 22 was used for the analysis, and a significance level of 5 percent was considered.

Results

The mean age of the patients was 40.90 ± 15.78 years, with a range of 18–85 years. The majority of patients were male (69.2%) and married (69.2%). Motor vehicle collisions (56.8%) followed by falls (20.4%) were the most common mechanisms of injury in patients. Multiple trauma (56%) and head trauma (40.4%) were the most prevalent types of trauma in the study population. The interventions performed included intubation in 23.6% of patients, splinting in 54.8%, and advanced immobilization techniques in 47.6% (Table 1).

Following analysis, 86.8% of patients had an initial diagnosis of traumatic brain injury (TBI). As shown in Table 2, the diagnostic accuracy in this study, including sensitivity, specificity, positive predictive value, and negative predictive value of the National Early Warning Score 2 (NEWS2) in prehospital care, was 0.70, 0.81, 0.96, and 0.29, respectively. The area under the curve (AUC) in Figure 1 was 79.2%. The cutoff point obtained was less than or equal to 5 ($P < 0.001$).

Table 1. Demographic characteristics of patients participating in the study

Freq.	Per.		Demographic data	
67	26.8		Less 30	
69	27.6		30–39	
44	17.6		40–49	
34	13.6		50–59	
36	14.4		60 and more	Age (year)
250	100		total	
15.78 ± 40.90			Mean ± SD	
18–85			Min–max	
77	30.8		Female	
173	69.2		Male	Sex
250	100		Total	
77	30.8		Single	
173	69.2		Married	Marital status
250	100		Total	
142	56.8		Car accident	
51	20.4		Falling	
43	17.2		Fights and conflicts	Mechanism of trauma
14	5.6		Suicide	
250	100		Total	
101	40.4		Head trauma	
2	0.8		Body trauma	
7	2.8		Limb trauma	Type of trauma
140	56		Multiple trauma	
250	100		Total	
191	76.4	Yes		
59	23.6	No	Intubation	
250	100	Total		
113	45.2	Yes		
137	54.8	No	Splinting	Care provided
250	100	Total		
131	52.4	Yes	Advanced immobilization techniques	
119	47.6	No		
250	100	Total		

The results of the independent *t*-test showed that the mean score of the NEWS2 in prehospital care for patients with an initial diagnosis of traumatic brain injury after 72 hours (12.3 ± 29.4) was significantly lower compared to other patients (08.3 ± 73.7) ($P < 0.001$).

In determining the diagnostic accuracy of NEWS2 in prehospital care for the early diagnosis of traumatic brain injury, the results of the present study show that this tool has an acceptable ability to diagnose patients with traumatic brain injury. A sensitivity of 70% means that NEWS2 can correctly identify 70% of people with TBI but misses 30% of TBI cases. This means that 3 out of 10 patients who have a brain injury are not correctly identified by this system. This can lead to delays in diagnosis and

appropriate treatment, especially in critical prehospital settings. The specificity of 81.8% means that NEWS2 can correctly identify 81.8% of people who do not have TBI. This result shows that NEWS2 performs relatively well in identifying people without injury, and the probability of false positives (misdiagnosis of injury) in this system is low. This Specificity provides more confidence in rejecting patients without injury.

A positive predictive value of 96.2% means that if NEWS2 says that a person has a brain injury, there is a very high probability (96.2%) that they have an injury. This indicates the high accuracy of NEWS2 in detecting positive cases. If NEWS2 shows brain injury, diagnostic and therapeutic measures can be taken with relatively high confidence. This very high value reinforces the utility of NEWS2 as a tool for early identification of possible TBI cases. The low negative predictive value of 3.29% means that if NEWS2 says that a person does not have a brain injury, there is only a 29.3% probability that they actually do not have an injury. In other words, if the test is negative, there is a high probability that the person has a brain injury but is not diagnosed. This low value is one of the main weaknesses of NEWS2.

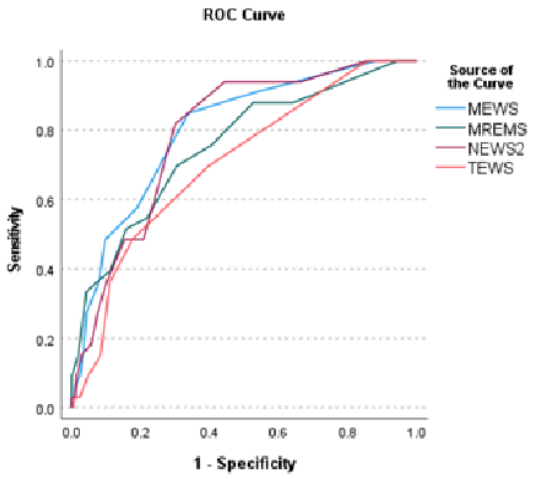

Figure 1. ROC curve of early warning scores in prehospital care for early detection of traumatic brain injury after 72 hours

The area under the curve (AUC) of 0.792 means that NEWS2 has a relatively good ability to discriminate between patients with and without TBI. Although the AUC is higher than 0.7 and indicates acceptable performance, it has not yet reached the excellent range (AUC close to 1). This value indicates that NEWS2 still has room for improvement compared to an ideal tool.

As seen in Table 2, the significance levels of the preliminary warning scores in prehospital care for all four tools are less than 0.001. Hence, all four models have a significant difference in predicting the initial diagnosis of traumatic brain injury after 72 hours compared to random chance. The highest sensitivity was observed in the TEWS (82.4), followed by the NEWS2 (70) for the initial diagnosis of traumatic brain injury after 72 hours. The highest specificity was observed in the MEWS (84.8) and then the NEWS2 (81.8) for the initial diagnosis of traumatic brain injury after 72 hours. The highest positive predictive value was found in the MEWS (96.6), followed by the NEWS2 (96.2) for the initial diagnosis of traumatic brain injury after 72 hours. The highest negative predictive value was found in the TEWS (29.6), followed by the NEWS2 (29.3) for the initial diagnosis of traumatic brain injury after 72 hours. The highest area under the curve was seen in the MEWS (0.802), followed by the NEWS2 (0.792).

As can be seen in Table 3, the results of the pairwise test showed that there was a statistically significant difference between the area under the curve of the National Early Warning Score 2 and the Modified Emergency Medicine ($P=0.0019$) and also the Triage Early Warning Score and

Table 2. Comparison of diagnostic accuracy of early warning scores in prehospital care for early diagnosis of traumatic brain injury after 72 hours

Sensitivity	Specificity	Positive predictive value	Negative predictive value	Cutoff	*p*	AUC	Standard deviation	Confidence interval (95%)	ESWs
70	81.8	96.2	29.3	5≤	>0.001	0.792	0.03	(0.737, 0.841)	NEWS 2
66.3	84.8	96.6	27.7	2≤	>0.001	0.802	0.03	(0.747, 0.850)	MEWS
82.4	48.4	91.3	29.6	4≤	>0.001	0.705	0.04	(0.645, 0.761)	TEWS
69.5	69.7	93.8	25.8	5≤	>0.001	0.754	0.04	(0.696, 0.806)	MREMS

Table 3. Pairwise comparison of diagnostic accuracy of early warning scores in prehospital care for early diagnosis of traumatic brain injury after 72 hours

AUC	Standard deviation	Confidence interval (95%)	Z	*p*	ESWs
0.047	0.03	(-0.03, 0.126)	1.202	0.229	NEWS 2~ MEWS
0.009	0.022	(-0.033, 0.053)	0.443	0.0657	NEWS 2~ TEWS
0.096	0.031	(0.035, 0.158)	3.099	0.0019	NEWS 2~MREMS
0.038	0.40	(-0.041, 0.117)	0.942	0.346	MEWS ~ TEWS
0.048	0.042	(-0.033, 0.131)	1.159	0.246	MEWS ~ MREMS
0.086	0.032	(0.024, 0.150)	2.712	0.006	TEWS ~ MREMS

the Modified Emergency Medicine ($P=0.006$) in the initial diagnosis of traumatic brain injury after 72 hours.

Discussion

The study aimed to compare the diagnostic accuracy of early warning scores (National Early Warning Score 2 (NEWS2), Modified Early Warning Score (MEWS), Triage Early Warning Score (TEWS), Modified Emergency Medical Score (MREMS)) in prehospital care for the diagnosis of traumatic brain injury.

The higher diagnostic accuracy of the National Early Warning Score 2 (NEWS 2) makes it a valuable tool in identifying patients with TBI. The results of the study by Martín-Rodríguez et al (2020) also showed that NEWS2, with an area under the curve of 0.888, has the best performance in detecting TBI (20). Also, the study by Najafi et al showed that the NEWS2 tool may be a more accurate measure for triaging patients in the prehospital emergency room than traditional criteria such as vital signs checking (23). Hu et al conducted a study in 2024 to compare the NEWS2 and GCS scores in predicting mortality in traumatic brain injury. The results of the study showed that NEWS2 is more accurate and practical than GCS in predicting in-hospital mortality in stroke and TBI patients (24), which is consistent with the present study.

Concerning the diagnostic accuracy of MEWS in prehospital care for the initial diagnosis of traumatic brain injury, the results of the present study showed that the mean MEWS score in prehospital care was significantly lower in patients with an initial diagnosis of traumatic brain injury than in other patients. In other words, MEWS has a similar performance to NEWS2 but with a slightly lower sensitivity. This indicates that it may not detect some cases of TBI. The higher specificity (84.8%) suggests that this score performs better in correctly identifying patients without injury. The high positive predictive value (96.6%) means that when MEWS detects injury, it is likely to be correct. However, the low negative predictive value indicates potential errors in rejecting patients without injury. The AUC (0.802) is slightly better than NEWS2, indicating a better performance in diagnosis. Kim et al conducted a study in 2021 to analyze and compare the predictive performance of different scores in patients with TBI. The results of their research showed that the area under the curve (AUC) for MEWS was 0.799, and the MEWS score showed acceptable performance in predicting TBI (25), which is consistent with the present study findings.

Regarding the determination of the diagnostic accuracy of TEWS in prehospital care for the initial diagnosis of traumatic brain injury, the results of the present study showed that the mean TEWS score in prehospital care was significantly lower in patients with an initial diagnosis of traumatic brain injury than in other patients. In other words, TEWS performs very well in sensitivity and correctly identifies a large number of patients with TBI. However, its low specificity indicates that many patients without injury may be misclassified as patients with TBI. Therefore, while TEWS can be helpful in critical situations for the diagnosis of injuries, it should be used with caution to avoid unnecessary treatment for patients without injury. The AUC of 0.705 indicates a relatively poorer performance than the previous two scores. In a study by Naidoo et al in 2014, which aimed to evaluate the effectiveness of TEWS in identifying random patients at risk of clinical deterioration, its sensitivity was 82.4%, and its specificity was 48.4% (26), which is consistent with the present study results.

Concerning the diagnostic accuracy of MREMS in prehospital care for the initial diagnosis of traumatic brain injury, the results of the present study showed that the mean MREMS score in patients with an initial diagnosis of traumatic brain injury was significantly lower than in other patients. In other words, MREMS has a balanced performance with similar sensitivity and specificity of about 70%. This indicates that it can effectively identify a significant number of injured patients but needs to improve the accuracy of diagnosing patients without injury. MREMS can be helpful in clinical decision-making, but it has less reliability compared to other scoring systems. The AUC (0.790) indicates the acceptable but not excellent performance of this score. de Souza Barbosa et al conducted a study in 2022 aimed at predicting in-hospital mortality of patients with penetrating trauma using the MREMS, and the results showed that MREMS has low power in predicting the prognosis of TBI patients. In their study, MREMS also performed moderately well with similar sensitivity and specificity of about 70% and was less reliable compared to other scoring systems (27), which is consistent with the results of the present study.

In 2017, Miller et al conducted a study to investigate the MREMS score in trauma and test its accuracy as a predictor of in-hospital mortality. The results of their study showed that the AUC of MREMS was 0.967 (28), which is not consistent with the present study results and indicates a higher score, which could be due to differences in the study population and other characteristics of the participants in the study.

To measure vital signs in patients participating in the study, thermometers and blood pressure monitors manufactured by different companies were used, which is one of the limitations of this study.

Conclusion

The results of this study emphasize the importance of implementing and evaluating standardized early warning tools in prehospital settings. The diagnostic accuracy of the early warning scores demonstrated in this study indicates that they can lead to more timely and accurate clinical decisions. While all four warning scores had a good

ability to detect intensive care unit admission, there were significant differences in their performance measures. The higher diagnostic accuracy of the National Early Warning Score 2(NEWS 2) makes it a valuable tool in identifying patients with TBI. The results of the present study can help in rapid and efficient diagnosis, better clinical decision-making, timely diagnosis and initiation of appropriate treatment, optimization of resource utilization and patient prioritization, and prediction of the need for intensive care unit admission in the prehospital setting.

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Validation: Elham Navab.
Visualization: Mohammad Ganji.
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Competing Interests
None.

Ethical Approval
All ethical principles were considered. The study was approved by the ethic committee of Tehran university of medical sciences (code IR.TUMS.FNM.REC.1402.129).

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